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Point Contact Technology for Silicon Heterojunction Solar Cells

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Abstract

This study deals with the introduction of Point Contact technology to enhance the efficiency of Interdigitated Back Contact (IBC) Silicon Heterojunction (Si-HJ) solar cells. For the study of point contacted Emitter and Back Surface Field (BSF), respectively Rear emitter (RE) Si-HJ cells and conventional Si-HJ cells are fabricated with different contact area fractions and different Emitter and BSF layers. It is shown that point contact area fraction should be above 16% to avoid performance losses for the different emitter stack. Emitter stack p-doped amorphous silicon on top of intrinsic amorphous silicon seems to be the most promising layer since it allows very high surface passivation level. Concerning point contacted BSF, further improvement of passivating stack and contact layer is still needed to allow an enhancement of cell efficiency. With an optimized geometry and further improvement of the passivating and contact layers, such structures may be suitable for an application on IBC Si-HJ devices.

Keywords: Silicon solar cells; Heterojunction; Point Contact

1. Introduction

Two technologies are currently used in the crystalline silicon (c-Si) photovoltaic industry to reach very high efficiencies. The first one is based on contacting highly doped (c-Si) layers through small openings in a passivating layer [1]. This "Point Contact" scheme allows efficiencies up to 25% (PERL cell [2]). An other way to achieve high performance on photovoltaic devices is the Si-HJ structure in which thin hydrogenated amorphous silicon (a-Si:H) layers are deposited onto a c-Si substrate. More than 23% efficiency has been obtained on large area (100 cm2) using this cell design [3]. Merging both technologies may be interesting for IBC solar cells where both emitter and BSF regions are placed at the rear side of the device [4]. This study aims to explore experimentally the point contact technology applied to Si-HJ

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structures and see whether this new concept could enhance the performances of IBC Si-HJ solar cells depending on the point contact area.

2. Experimental

Front and rear Emitter Si-HJ cells (25cm^2) have been fabricated on n-type crystalline silicon FZ wafers (FIG. 1). The front side of the substrate is textured and the rear side polished in KOH solution. After wafer cleaning, the passivating stack has been deposited in a PECVD (Plasma Enhanced Chemical Vapor Deposition) chamber and patterned by masking (screen printed paste) and wet chemical etching.Figure. 1.

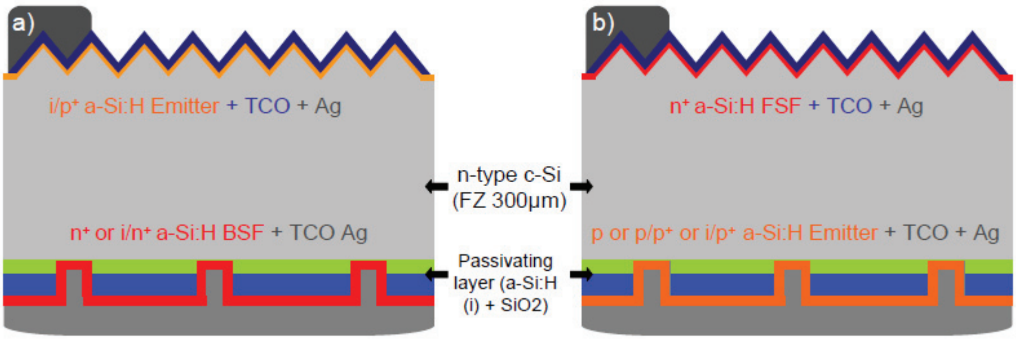

Fig. 1. Point contacted Si-HJ solar cell structures with: (a) Front Emitter (b) Rear Emitter

Different a-Si:H layers were then deposited at the front and the rear of the wafers also by PECVD:

(1) An emitter made of a p+ a-Si:H layer, stacked (or not) with an intrinsic (i) or lightly doped p-type a-Si:H buffer layer.

(2) A BSF made of a n+ a-Si:H layer, stacked (or not) with an intrinsic-type a-Si:H buffer layer.

An ITO layer (Indium Tin Oxide) is used at the front and at the rear side as contact material onto the doped a-Si:H layers. The metallization consists in screen printed Ag at the front and sputtered Ag at the rear. The solar cells were separated from the substrate by Laser scribing and their I-V curves measured under AM1.5 illumination. In this study, the point contact area has been varied using different distances between holes in the passivating layer (Fig. 2).

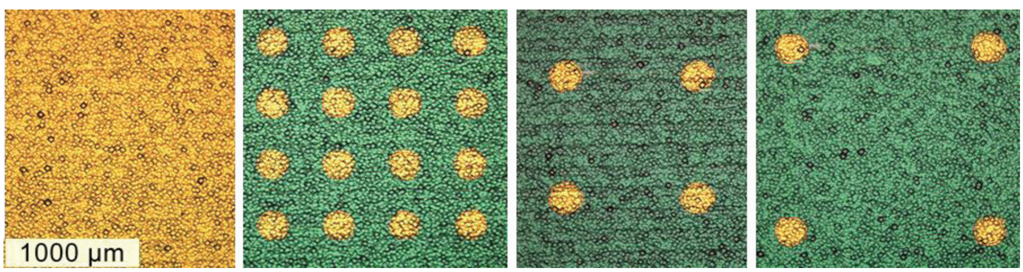

Fig. 2. Images of the rear surfaces with different distances between the patterned holes. From left to the right a point contact area of 100% (no passivating layer), 16%, 4% and 2% is obtained

3. Results and discussion

3.1. Point Contacted a-Si:H Rear Emitter (RE)

The influence of the point contact area as well as the emitter stack (p+, p/p+ or i/p+ a-Si:H) on the electrical parameters of Si-HJ RE cells is shown on Fig. 3. Our results show an enhancement of the V_{OC} values with a lower contact area fraction, whereas the short circuit current density (J_{SC}) and Fill Factor (FF) values decrease.

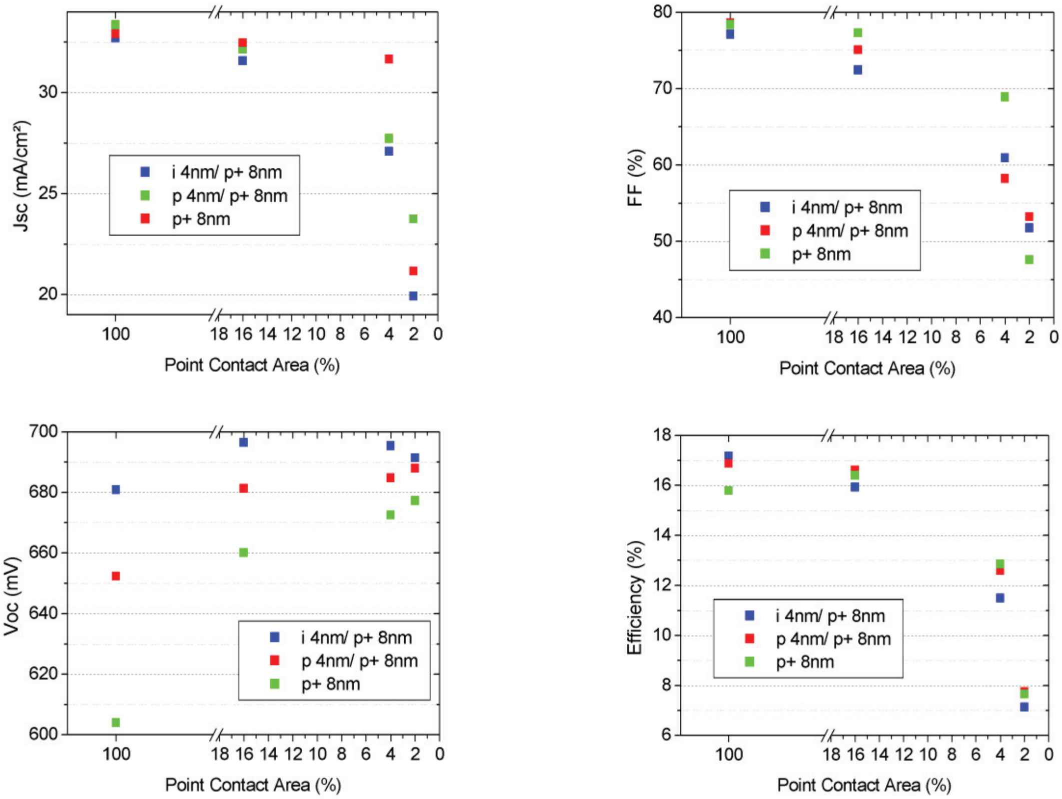

Fig. 3. Electrical parameters of Si-HJ RE cells depending on the contact area and the emitter stack

The trend in current is mainly due to minority carrier collection losses since Light Beam Induced Current (LBIC) measurements (Fig. 4) show really low current collection in the gap between openings. Moreover, this effect increases with larger gap values. Indeed, the calculated diffusion length of holes for a n-type substrate 3 Ω.cm passivated with amorphous silicon is:

$$L_h=[(D_h x \ \tau_{eff})]^{1/2}=980\mu m \tag{1}$$

D_h is the diffusion constant of holes in the substrate and τ_{eff} the minority carrier effective lifetime in the substrate passivated with a-Si:H (measured with Sinton Lifetime tester). In the case of low contact area fraction, L_h is lower than the distance between two openings. Consequently, holes photogenerated far from the junction recombine before reaching it. To avoid this effect, a better passivation level must be obtained between the holes.

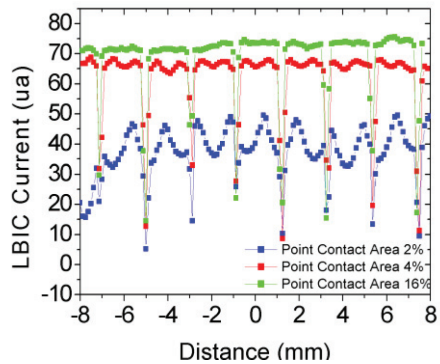

Fig. 4. LBIC current at wavelength 406 nm for point contacted i/p+ layer with different point contact area fractions

Concerning the FF losses SunsVoc measurement at 1 sun shows very high Pseudo Fill Factor (PFF) (Fig.5) for low contact area fraction which means that the loss in FF is mainly due to series resistance either in the substrate (lateral resistance) or in the a-Si:H RE layer.

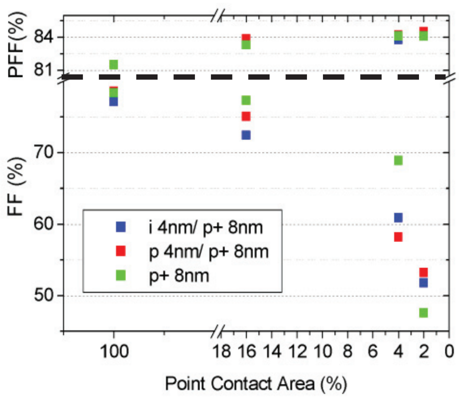

Fig. 5. Comparison between FF measurement and Pseudo FF at 1sun for different RE layers and Point contact area fractions

As a conclusion, for the different a-Si:H emitter stacks tested in this study, the point contacts must not cover less than 16 % of the surface to avoid performance losses. Indeed, the increase of the quality of the surface passivation introduced by the point contact does not compensate the losses in minority carrier collection and conductivity in this range of RE contacted fraction. As a result, higher contact area fraction should be tried in further studies to find if there is an optimum in geometry. The most promising layer to be contacted locally is i/p+ since it allows V_{OC} between 680mV and 700mV and a large potential of improvement in FF and J_{SC} for contact area fraction between 16% and 100%.

3.2. Point Contacted a-Si:H BSF

The influence of the point contact area as well as the BSF stack (n or i/n a-Si:H) on the electrical parameters of standard (front emitter) Si-HJ cells is shown on Fig. 6.

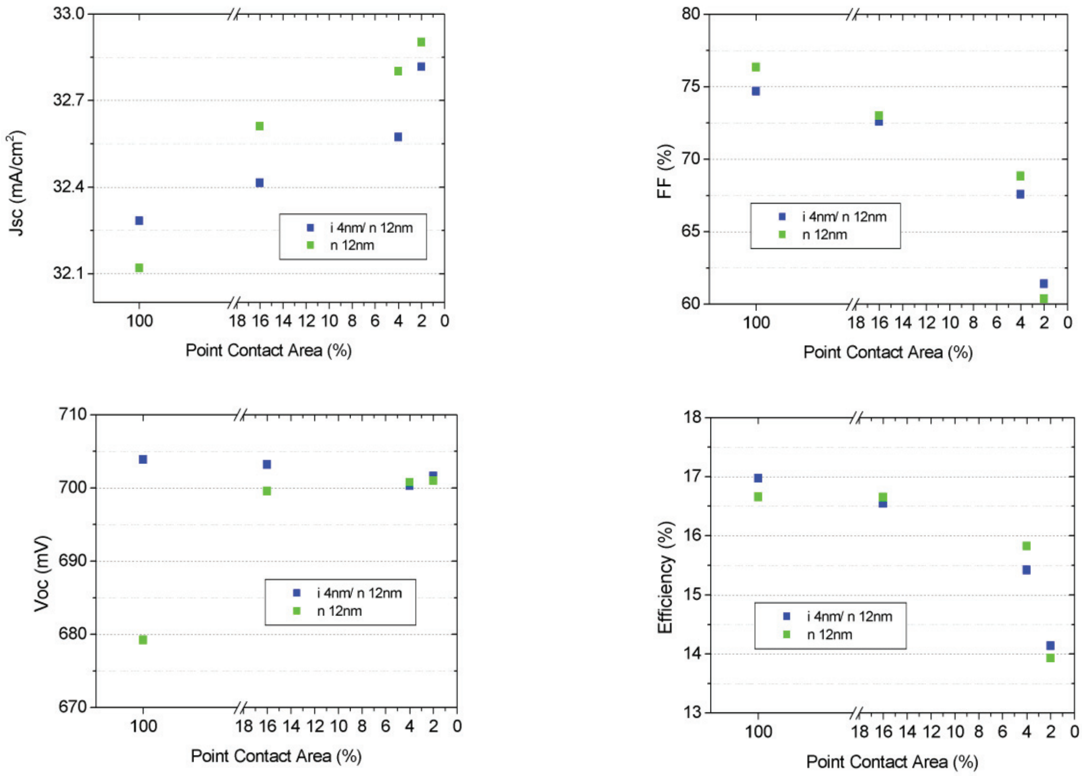

Fig. 6. Electrical parameters of Si-HJ RE cells depending on the contact area and the BSF stack

Interestingly the J_{SC} values increase with a smaller point contact area for both BSF stacks. The same trend is observed (Fig.7) for the reflectivity of the rear of the cell which means that the passivating stack a-Si:H/ SiO_2 located between the opening reflects more light than the BSF layer. Concerning the V_{OC}, when a i/n a-Si:H BSF is used no improvement is observed (Fig.6) due to the very high surface passivation level already reached with this stack whereas with a n-type a-Si:H BSF a large increase is observed. The same trend as for RE Si-HJ cells is obtained on the FF value due to an increase of series resistance with smaller contact area. Almost the same efficiency level as conventional Si-HJ cells is obtained through the use of point contacted BSF.

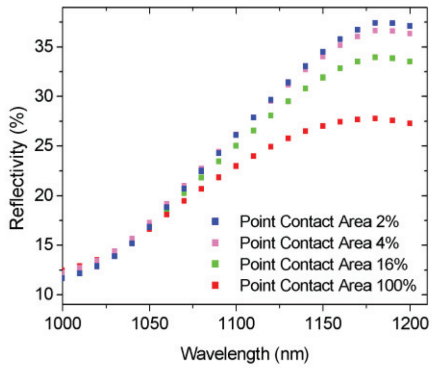

Fig.7. Reflectivity of cells with different contact area fractions of BSF at Wavelength from 1000nm to 1200nm

As a conclusion, since the reflection is increased by the passivating stack it could be very interesting to keep low contact area fraction to enhance the J_{SC} of the cell. However, further work should be done on the passivating stack to enhance V_{OC} values. The conductivity of i/n stack must be increases as well to avoid resistive losses at low contact area fraction.

4. Conclusion

Promising results have been obtained for point contacted Si-HJ Emitter and BSF. Up to now, no improvement in efficiency has been observed but it seems that better results could be reached with an optimized geometry for point contacted RE and further improvements of the passivating stack and contact layers for point contacted BSF. Further studies must be done to confirm that such structures are suitable for an application on IBC Si-HJ devices.

Acknowledgements

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